right in the mouth. Hence, there seems now to be definite proof that the front teeth of Eoanthropus resembled those of an ape, and its recognition as a genus distinct from Homo is apparently justified.

The association of such a mandible with a skull of large brain-capacity is considered by Dr. Woodward most improbable, and he has made further studies of the brain-case with the help of Mr. W. P. Pycraft, who has attempted a careful reconstruction of the missing base. Dr. Woodward now concludes that the only alteration necessary in his original model is a very slight widening of the back of the parietal region to remedy a defect which was pointed out to him by Prof. Elliot Smith when he first studied the brain-cast. The capacity of the brain-case thus remains much the same as he originally stated, and he maintains that Prof. Keith has arrived at a different result by failing to recognise the mark of the superior longitudinal sinus on the frontal region and by unduly widening that on the parietal region.

It is understood that Mr. Dawson and Dr. Woodward will offer an account of the season's work to the Geological Society at an early meeting, and Prof. Elliot Smith will include a detailed study of the brain-cast of Eoanthropus in a memoir on primitive human brains which he is preparing for the Royal Society.

THE BRITISH ASSOCIATION AT BIRMINGHAM.

SECTION C.

GEOLOGY.

OPENING ADDRESS BY PROF. E. J. GARWOOD, PRESIDENT OF THE SECTION.

ON the last occasion when members of the British Association met in Birmingham, in 1886, this section was under the able presidency of my friend Prof. T. G. Bonney, who at that time occupied the chair of geology at University College, London. Fifteen years later I succeeded him on his retirement from that post, and to-day I succeed him as president of this section, at the second meeting of the Association at Birmingham; and again I feel the same diffidence in following him as I did on the former occasion.

In his address in 1886 Prof. Bonney discussed the "Application of Microscopic Analysis to Discovering the Physical Geography of Bygone Ages."

Strangely enough, this title might apply almost equally well to the subject of my address to-day; but whereas Prof. Bonney employed for his purpose the evidence obtained from observations on mechanical sediments, I propose to deal with certain organically formed deposits with the same object

More than twenty years ago, whilst engaged in the study of the lower carboniferous rocks of Westmorland, I noticed the occurrence of certain small concretionary nodules of very compact texture, in the dolomites near the base of the succession in the neighbourhood of Shap.

Shortly afterwards, when examining the Bernician rocks of Northumberland, I again met with similar compact nodular structures. It was obvious, however, even at that time, that the Northumberland specimens occurred here at a much higher horizon than those which I had observed in Westmorland.

More recently, whilst studying the lithological characters of the lower carboniferous rocks of the North of England and the Border country, I have been still further impressed by the abundance of these nodular structures at several horizons, and the large tracts of country over which they extend. An examination of these nodules in thin sections showed their obvious organic character, and I was at first inclined to refer them to the Stromatoporoids. Dr. G. J. Hinde, who was kind enough to examine my specimens from the Shap district, reported, however, that they were probably not Stromatoporoids, but calcareous algæ, and referred me to the descriptions of Solenopora published by the late Prof. Nicholson and Dr. Brown.

Since then I have examined a large number of nodules collected from different horizons in the lower carboniferous rocks of Britain and Belgium; and the examination has convinced me that the remains of calcareous algæ play a very much more important part in the formation of these rocks than has hitherto been generally realised.

The majority of geologists in this country have been slow to recognise the importance of these interesting organisms, and, with the notable exception of Sir Archibald Geikie's text-book, we find but scant allusion in English geological works of reference to the important part played by calcareous algæ in the formation of limestone deposits.[1]

From the more strictly botanical standpoint, however, we are indebted to Prof. Seward for an admirable account of the forms recognised as belonging to this group, up to the date of the publication of his text-book on fossil plants in 1898; while in an article in *Science Progress,* in 1894, he has also dealt with their importance from a geological point of view.

Since these publications, not only have several new and important genera been discovered in this country and abroad, but the forms previously known have also been found to have a very much wider geological and geographical range than was formerly suspected. For these reasons I venture to hope that a summary of our knowledge of the part they play as rock builders, more especially in British deposits, will serve to stimulate an interest among geological workers in this country in these somewhat neglected organisms.

Previous to 1894, in which year Dr. Brown first referred Solenopora to the Nullipores, with the exception of the Jurassic and Tertiary Characeæ, we meet with little, if any, reference to the occurrence of fossil calcareous algæ in British deposits.

Indeed, in this country the subject has attracted but few workers, and they can almost be counted on the fingers of one hand. When we have mentioned the late Prof. H. A. Nicholson and Mr. Etheridge, jun., Mr. E. Wethered, Dr. Brown, Dr. Hinde, and Prof. Seward, we have practically exhausted the list of those who have contributed to our knowledge of the subject. To these we may add the name of Mrs. Robert Gray, whose magnificent collection of fossils from the Ordovician rocks of the Girvan district has always been freely placed at the disposal of geological workers, and has furnished numerous examples of these organisms to Prof. Nicholson and the officers of the Geological Survey.

It was Nicholson and Wethered who first recognised the important part played in the formation of limestones by certain organisms, which, though referred at the time to the animal kingdom, are now generally considered to represent the remains of calcareous algæ.

The presence of these organisms in a fossil state, especially in the older geological formations, has only been recognised in comparatively recent years; though it was suggested as long ago as 1844 by Forchhammer[2] that fucoids, by abstracting lime from sea-water, probably contributed to the formation of Palæozoic deposits. When we remember that it was not until the researches of Phillipi were published in 1837 that certain calcareous deposits were discovered to be directly due to the growth of living forms of lime-secreting algæ, it is not surprising that, only in comparatively recent years, has the importance of the fossil forms as rock-builders in past geological formations been recognised.

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[1] Geikie. "Text-book of Geology." 4th ed., vol. i, pp. 605 and 611. 1903.

[2] British Association, 1844, p. 155.

The original genera established by Phillipi—namely, Lithothamnion and Lithophyllum—are known now to have a wide distribution in the present seas, and it is therefore natural that it was members of these groups which were the first to be recognised in a fossil state in Tertiary and, subsequently, in upper cretaceous rocks.

Thus in 1858, Prof. Unger of Vienna showed the important part played by Lithothamnion in the constitution of the Leithakalk of the Vienna Basin, while seven years later Rosanoff contributed further to our knowledge of tertiary forms. In 1871 Gümbel published his monograph on the "so-called Nullipores found in limestone rocks," with special reference to the Lithothamnion deposits of the Danian or Maestricht beds. Since then Lithothamnion has also been reported from Jurassic rocks, and even from beds of Triassic age, though in the latter case, at all events, the reference to this genus appears to require confirmation. In this country the recognition of fossil calcareous algæ dates from a considerably later period. It will be best first to review the chief genera which appear to be referable to the calcareous algæ, and afterwards to show the part they play as rock-builders in the different geological formations.

Two important genera are usually recognised at the present day as occurring in the British Palæozoic and Mesozoic rocks—namely, Solenopora and Girvanella—and to these I propose to add Wethered's genus, Mitcheldeania, together with certain new forms from the Carboniferous rocks of the North of England, which appear also to be referable to this group.

Solenopora.

This genus was first created by Dybowski in 1877 for the reception of an obscure organism, from the Ordovician rocks of Esthonia, which he described under the name *Solenopora spongioides,* and regarded as referable to the Monticuliporoids.

Nicholson and Etheridge in 1885 (*Geol. Mag.*, p. 529) showed that the form described by Billings in 1861 as *Stromatopora compacta,* from the Black River limestones of North America, was in reality Dybowski's genus Solenopora, and in all probability was specifically identical with the form from Esthonia. Moreover, they considered that the organism they themselves had described under the name of *Tetradium Peachii* in 1877, from the Ordovician rocks of Girvan, was also referable to Billing's species, though perhaps a varietal form. Thus *Solenopora compacta* was shown to have a very wide distribution in Ordovician times.

Nicholson in 1888 defined the genus as including "Calcareous organisms which present themselves in masses of varying form and irregular shape, composed wholly of radiating capillary tubes arranged in concentric strata. The tubes are in direct contact, and no coenenchyma or interstitial tissue is present. The tubes are thin-walled, irregular in form, often with undulated or wrinkled walls, without mural pores, and furnished with more or fewer transverse partitions or tabulæ." [3]

At that time Nicholson still considered Solenopora as representing a curious extinct hydrozoon, though already, in 1885, Nicholson and Etheridge had discussed its possible relationship to the calcareous algæ. They did not, however, consider that there was sufficient evidence for concluding that the true structure of Solenopora was cellular, but added: "If evidence can be obtained proving decisively the existence of a cellular structure in Solenopora, then the reference of the genus to calcareous algæ would follow as a matter of course." [4]

In 1894 Dr. A. Brown investigated more fully the material which had been placed in his hands by Prof. Nicholson, and gave an account of all the forms referable to Solenopora known at that date.

To those already recorded, he added descriptions of four new species from the Ordovician rocks—namely, *S. lithothamnioides, S. fusiformis, S. nigra,* and *S. dendriformis,* the two latter being from the Ordovician rocks of Esthonia.

In the same paper also he published for the first time a description of a new species of Solenopora from the Jurassic rocks of Britain, to which Nicholson, in manuscript, had already assigned the name of *S. jurassica,* though, as will be pointed out later, it is probable that two distinct forms were included by Brown under this name.

This record of Solenopora from the lower Oolites of Britain extended the known range of this genus, for the first time, well into the Jurassic period. In this paper Brown first brought forward good evidence for removing Solenopora from the animal kingdom, and placing it among the coralline algæ, and Prof. Seward, in Vol. i. of his work on fossil plants, considers that there are good reasons for accepting this conclusion.

At the time of the publication of Dr. Brown's paper, and for some years afterwards, the only formations in which Solenopora was known to occur were the upper Ordovician and the lower Oolites. The diversity of forms, however, met with in the Ordovician rocks, and their widespread distribution, pointed to the probability of the existence of an ancestral form in the older rocks, while it also appeared incredible that no specimens of intervening forms should have been preserved in the rocks representing the great time-gap between the Ordovician and Jurassic formations.

In this connection Prof. Seward remarks [5]. "It is reasonable to prophesy that further researches into the structure of ancient limestones will considerably extend our knowledge of the geological and botanical history of the Corallinaceæ." This prophecy has been amply fulfilled, especially as regards this particular genus, and recent discoveries go far towards filling the previously existing gaps in our knowledge of the vertical distribution of this interesting genus.

Thus the recent detection in the lowest Cambrian rocks of the Antarctic continent of a form which appears to be referable to this genus enables us to trace the ancestry of Solenopora back almost to the earliest rocks in which fossils have yet been discovered, while the gap in the succession which previously existed between the Ordovician and Jurassic forms was decreased by the description in 1908 by Prof. Rothpletz of a new species *Solenopora Gothlandica,* from the Silurian rocks of the Faröe Islands in Gotland.[6] A large number of deposits, however, still remained, between the Gotlandian and lower Jurassic beds, from which no example of Solenopora had so far been recorded.

The identification, therefore, a few years ago, by Dr. G. J. Hinde, of examples of this genus from among the nodules I had collected from the Shap dolomites, is of considerable interest, as the presence of Solenopora in the lower Carboniferous rocks of this country materially decreases the gap in our knowledge of the succession of forms belonging to this genus, which had previously existed.

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[3] "Geol. Mag., 1888, Dec. 3, vol. v, p. 19.

[4] "Geol. Mag., 1885, Dec. 3, 2, p. 534.

[5] *Op. cit.*, p 190.

[6] "Kungl. Svenska, Vets. akad. Handl." Bd. 42, No. 5, 1908, p. 14, pl. iv., pp. 1-5.

Girvanella.

This organism, which is now known to be widely distributed in the Palæozoic and Mesozoic rocks of this country, was originally described in 1878 by Nicholson and Etheridge, jun., from the Ordovician rocks of the Girvan district. The genus was established to include certain small nodular structures composed of a felted mass of interlacing tubes, having a width of 10 and 18 μ, the cells being typically simple, imperforate tubes without visible internal partitions. The geno-type, *G. problematica,* was, however, at that time referred to the Rhizopods and regarded as related to the arenaceous foraminifera ("Silurian fossils in the Girvan district," 1878, p. 23). In 1888 Nicholson, in redescribing this genus in the *Geological Magazine,* compares Girvanella with the recent form *Syringammira fragillissima* of Brady.

More recently Mr. Wethered has shown that an intimate association frequently exists between Girvanella tubes and oolitic structure, and he has described several new species of Girvanella, from the Palæozoic rocks and also from certain Jurassic limestones.

The reference of Girvanella to the calcareous algæ, though not yet supported by incontestable evidence, has been advocated by several writers in recent years. Even as long ago as 1887, Bornemann, in describing examples of Siphonema (Girvanella Nich.), which he had discovered in the Cambrian rocks of the Island of Sardinia, suggested that this organism might belong to the calcareous algæ.

In 1891 Rothpletz noticed that some of the specimens of Girvanella which he had examined were characterised by dichotomous branching of the tubes; on this account he removed the genus from the Rhizopods to the calcareous algæ, placing it provisionally among the Codiaceæ. Three years later Dr. A. Brown, in summing up the evidence in favour of the inclusion of Solenopora among the nullipores, expressed the opinion that Girvanella might ultimately come to be regarded as referable to the Siphoneæ Verticillatæ.

In 1898, however, this genus was still only doubtfully placed with the calcareous algæ, for Seward, in his work on fossil plants,[7] remarks: "The nature of Girvanella, and still more its exact position in the organic world, is quite uncertain. . . . We must be content for the present to leave its precise nature still *sub judice,* and, while regarding it as probably an alga, we may venture to consider it more fittingly discussed among the Schizophyta than elsewhere."

In 1908, however, Rothpletz, in discussing the relationship of Spherocodium and Girvanella, reaffirms his opinion that the latter must be referred to the Codiaceæ.[8]

Mitcheldeania.

This genus was first described by Mr. Edward Wethered from the lower Carboniferous beds of the Forest of Dean[9] under the name of *Mitcheldeania Nicholsoni*; it was referred by him to the Hydractinidæ, and considered to be allied to the Stromatoporoids. The figure accompanying this paper unfortunately fails to show any of the characters of the organism, but a better figure of the same species was subsequently published in the Proceedings of the Cotteswold Naturalists' Field Club.[10]

In 1888 Prof. H. A. Nicholson published in the *Geological Magazine* figures and descriptions of a new species of this genus (*M. gregaria*), and redefined the genus as having "the form of small, rounded, or oval calcareous masses made up of capillary tubes of an oval or circular shape, which radiate from a central point or points, and are intermixed with an interstitial tissue of very much more minute branching tubuli." He compares the larger tubes to zooidal tubes, and states that they "communicate with one another by means of large, irregularly-placed foramina resembling "the mural pores" of the Favisitidæ, and they occasionally exhibit a few irregular transverse partitions or tubulæ."

With regard to the systematic position of this genus, Nicholson remarks: "In spite of the extreme minuteness of its tissues, the genus Mitcheldeania may, I think, be referred with tolerable certainty to the Cœlenterata . . . its closest affinities seem to be with the hydrocorallines . . . on the other hand, all the known hydrocorallines possess zooidal tubes which are enormously larger than those of Mitcheldeania; and there are other morphological features in the latter genus which would preclude its being actually placed, with our present knowledge, in the group of the Hydrocorallinæ."

Since this description by Prof. Nicholson, no further account of this organism, so far as I am aware, has been published, and its reference to the Hydrozoa rests on Prof. Nicholson's description.

During the past few years I have collected a large amount of material from both of the type localities from which Mr. Wethered and Prof. Nicholson obtained their specimens, and an examination of this material has impressed me strongly with the resemblance of Mitcheldeania to forms such as Solenopora and Girvanella, now usually classed among the calcareous algæ. In the rocks in which it occurs Mitcheldeania appears as rounded and lobulate nodules, breaking with porcellanous fracture and showing concentric structure on weathered surfaces, very similar to nodules of Solenopora; while under the microscope the branching character of the tubules and their comparatively minute size appear to separate them from the Monticuliporoids. Prof. Nicholson appears to rely on the presence of pores, which he thought he observed in the walls of both the larger and finer tubes, for the inclusion of this genus with the hydrocorallines, though he appeared to be doubtful about their occurrence in the interstitial tubuli. An examination of a large number of slides has failed to convince me of the presence of pores, even in the larger "zooidal tubes." The large "oval or circular" apertures noticed by Nicholson appear to be either elbows in the undulating tubes cut across where these bend away from the plane of the section, or places where a branch is given off from a tube at an angle to the plane of the section. If this view be accepted, there appears to be no sufficient reason why Mitcheldeania should not be ranged with Solenopora and other similar forms, and included among the calcareous algæ—a position which its mode of occurrence and general structure has led me, for some time, to assign to this organism.

In addition to the three chief forms described above from British rocks, a study of numerous thin sections from the Lower Carboniferous rocks of the north-west of England has revealed the presence of several distinct organisms, which will, I think, eventually be found to be referable to the calcareous algæ.

This meagre list appears to exhaust the genera known at the present time from the Lower Carboniferous rocks of Britain, while the only additional genus so far recorded from the Mesozoic and Tertiary

[7] Vol. i, p. 125.

[8] Rothpletz. "Ueber Algen und Hydrozoen," *op. cit.*

[9] "Geol. Mag.," Dec. 3, 3, cccccxxxv, 1886.

[10] Vol. ix, p. 77, pl. v., 1886.

rocks of this country (if we except Rothpletz's sub-genus Solenoporella) is Chara from the Wealden beds of Sussex, the uppermost Jurassic of the Isle of Wight and Swanage, and the Oligocene of the Isle of Wight.

Outside of this country the literature on fossil calcareous algæ is much more extensive. The interest originally aroused on the Continent by the writings of Phillipi, of Unger of Vienna, Cohn, Rosanoff, Gümbel, Saporta, and Munier-Chalmas has been further maintained in our own time by Bornemann, Steinmann, Früh, Solms-Laubach, Rothpletz, Walther, Kiaer, and others; while the more favourable conditions which obtained for the growth of these organisms, especially during Silurian, Triassic, and Tertiary times, has afforded a much wider field for their observation.

Thus, in addition to the forms recorded from this country, an important part has been played by members of the family of the Dasycladaceæ, together with such genera as Spherocodium, Lithothamnion, and Lithophyllum.

It is now time to turn to the consideration of the part played by these organisms in the formation of the sedimentary rocks through the successive geological periods.

ARCHÆAN.

In the Archæan rocks no undoubted remains of Algæ have, so far as I am aware, yet been recorded, but Sederholm considers that certain small nodules in the Archæan schists of Finland may represent vegetable remains. I may also perhaps here refer to some curious oolitic structures which I met with in Spitsbergen in 1896 when examining the rocks of Hornsund Bay. These oolites occur on the south side of the bay, and are closely connected with massive siliceous rocks which may represent old quartzites. The whole series is much altered, and detailed structure cannot now be made out. The rocks occur apparently stratigraphically below the massif of the Hornsund Tind, and may belong either to the Archæan or the base of the Heckla Hook series. As, however, similar rocks have not been recorded from the type district of Heckla Hook, they may be referred provisionally to the Algonkian, and may represent the quartzites and earthy limestone of the Jotnian series of Scandinavia. They are mentioned here in connection with Mr. Wethered's view that oolites are essentially associated with the growth of Girvanella.

CAMBRIAN.

Passing on to the Palæozoic rocks, we find in the Cambrian deposits very few indications that calcareous algæ played any considerable part in their formation.

This is no doubt due, in part, to the conditions under which these deposits accumulated in the classical localities where true calcareous deposits are typically absent. In the Durness limestone, however, where considerable masses of dolomites occur, the conditions would appear at first sight to have been more suitable for the growth of these organisms; but even here the slow rate of accumulation and the large amount of contemporaneous solution may have militated against their preservation. At the same time, it is possible that a systematic search in the calcareous facies of the Cambrian rocks in the north of Europe and America might result in the discovery of the remains of some members of this group. That there is ground for this suggestion is shown by the recent work in the Antarctic continent.

Prof. Edgworth David and Mr. Priestly have discovered among the rocks in the north-west side of the Beardmore Glacier dark grey and pinkish-grey limestone containing the remains of Archæocyathinæ, Trilobites, and sponge spicules, together with abundant remains of a small calcareous alga referred provisionally to Solenopora; from the photographs exhibited by Prof. David on the occasion of his address to the Geological Society I have little doubt that this reference is correct.

A further occurrence is also reported from fragments of a limestone breccia collected by the Southern party from the western lateral moraine of the same glacier. Speaking of the fauna discovered in this limestone, Prof. David remarks: "The whole assemblage is so closely analogous with that found in the Lower Cambrian of South Australia as to leave no doubt as to the geological age of the limestones from which these fragments are derived."[11] This discovery, therefore, extends the vertical range of this widely spread genus down to the oldest Palæozoic rocks. It is interesting to note that the rocks in which the Solenopora occurs contain a development of pisolite and oolite, and that this is also the case in the Australian equivalents In 1887 and again in 1891 Bornemann described and figured species of Siphonema and Confervites[12] from the Archæocyathus limestones of Sardina. As regards the former genus, it was shown by Dr. Hinde[13] to be congeneric with Girvanella (Nich and Eth). It is of interest, however, to note that Bornemann describes this form as a calcareous alga, and compares it with existing sub-aerial algæ growing on the surface of limestone rocks in Switzerland. The latter is stated by Seward to be possibly "a Cambrian algæ, but the figures and descriptions do not afford by any means convincing evidence."

More recently, in 1904, Dr. T. Lorenz has described remains of Siphoneæ from the Cambrian rocks of Tschang-duang in Northern China, for which he erects two new genera, Ascosoma and Mitscherlichia, placing them in a new family, the Ascosomaceæ. These algæ build important beds of limestone, the individuals often attaining a length of 4 cm. and a thickness of 1½ cm. In 1907 Bailey reported Girvanella associated with oolites in the lowest Cambrian Man-t'o beds in China. It is probable, therefore, that as our knowledge of these rocks is extended calcareous algæ will be found to play an important part in the Cambrian limestones of the Asiatic continent and Australia.

ORDOVICIAN.

In the Ordovician rocks, the remains of calcareous algæ become much more abundant. They are very widely distributed, and for the first time they become important rock-builders. In Britain, the chief genera met with are Girvanella and Solenopora. These two organisms occur abundantly in the Scottish Ordovician rocks of the Girvan area, where they appear to have contributed largely to the limestones of the Barr series in Llandeilo-Caradoc times.

As already mentioned, the genotype of Girvanella—*G. problematica*—was originally described by the late Prof. Nicholson and Mr. Etheridge, jun., from the Craighead limestone, where it occurs in great numbers in the Craighead limestone at Tramitchell. The officers of the Geological Survey also report it from the Stinchar limestone of Benan Hill.

It occurs in the form of small rounded or irregular nodules, varying in diameter from less than a millimetre to more than a centimetre—many of the nodules showing marked concentric structure. During a recent visit to Girvan I was much struck by the important part played by this organism in the formation of these upper compact limestones In Benan Burn, where these beds are admirably exposed, the

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[11] Eleventh Inter. Congress Report, 1910, p. 775.

[12] "Nova. Acta. Coes. Leop. Car.," 1887 and 1891.

[13] Hinde, "Geol. Mag.," 1887, p. 226.

Girvanella nodules occur conspicuously on the weathered surfaces, being so abundant as to constitute thick layers of limestone.

Solenopora compacta, var. *Peachii,* which, likewise, forms important masses of limestone, occurs, like *Girvanella problematica,* in the Girvan area, but at a somewhat lower horizon, namely, in the nodular limestone and shales forming the lower sub-division of the Stinchar limestone. It was originally described from pebbles in the Old Red Conglomerate of Habbie's Howe by Nicholson and Etheridge, jun., under the name *Tetradium Peachii,* and was subsequently discovered to occur plentifully in the Ordovician limestone at Tramitchell and Craighead, and to be synonymous with *Solenopora compacta* (Bill). In the shales associated with the nodular limestone of Craighead it occurs as spheroidal and botryoidal nodules up to $1\frac{1}{2}$ in. in diameter; while in the limestone itself the nodules may have a diameter of 3 in. On freshly fractured surfaces it appears as buff-coloured on brownish spots, having a compact porcellanous texture, while weathered surfaces often show a concentric structure. Under the microscope the tubes of this species vary in diameter from 50–80 μ.

In the Geological Survey Memoir it is also recorded, under the original name of *Tetradium Peachii,* from the Stinchar limestone of Benan Burn, Millenderdale, and Bougang, where it is accompanied by two other species, *S. filiformis* and *S. fusiformis,*[14] which contributes conspicuously to the deposit, often forming large masses of limestone. The horizon of the Stinchar limestone is correlated by Prof. Lapworth with the Craighead limestone, and considered to represent the summit of the Llandeilo or the base of the Caradoc of the Shropshire district. It is of interest to note that Solenopora is here accompanied at times by well-marked oolitic structure, and that the same is true of the pebbles with which it is associated in the conglomerate at Habbie's Howe.

Although the marked development of Solenopora found in the Stinchar limestone ceases with the advent of the Benan conglomerate, the genus appears to have survived in the district into Upper Caradoc times, for Dr. Brown describes a new species (*S. lithothamnioides*) from Nicholson's collection from the Ordovician (? Silurian) at Shalloch Mill, where it occurs in conical masses the size of a walnut. The only beds in which we might expect algæ to occur in this locality are the nodular limestones or Dionide beds of the Whitehouse group of Prof. Lapworth's classification, but there is no mention of Tetradium or Solenopora from this locality in the fossil lists cited from Mrs. Gray's collection in the survey memoir.

As this point is of some interest, I have consulted Mrs. Gray, who very kindly sent me some small nodules which she had collected from the Whitehouse beds of Shalloch Mill. On slicing one of these I find that it is undoubtedly a Solenopora, and probably the species figured by Dr. Brown as *S. lithothamnioides.* A tangential section cut from this specimen shows clearly why the original specimen of Solenopora from Craighead was mistaken for Tetradium by Nicholson and Etheridge, jun.

South of the Scottish border there is, so far as I am aware, only one locality from which calcareous algæ have been recorded in rocks of Ordovician age, namely, Hoar Edge in Shropshire. Here large examples of *Solenopora compacta* were obtained in 1888 by Prof. Lapworth from the calcareous layers near the base of the Hoar Edge sandstone. The specimens were handed to Prof. Nicholson, who records the circumstance in his description of *S. compacta* in the *Geological Magazine* for 1888. The form occurs here at the base of the Caradoc beds, and therefore at a horizon which corresponds closely to that of the Craighead limestone of Girvan.

Prof. Lapworth also informs me that he has obtained specimens of Solenopora from a limestone in south-west Radnorshire. As the upper portion of the limestone in which it is found contains a Silurian fauna, it is possible that it is here present at a higher horizon, though the constancy with which it occurs elsewhere, in beds of Llandilo-Caradoc age, would seem to point to the possible presence of beds of Upper Ordovician age in this area. In any case, its occurrence here is of considerable interest.

Foreign Ordovician.

Outside of Britain, one of the most interesting developments of calcareous algæ in rocks of Ordovician age occurs in the Baltic provinces.

As already stated, Solenopora was first recorded from Herrküll in Esthonia, by Dybowski under the name of *Solenopora spongioides.* It occurs here in the Upper Caradoc or Borckholm beds of Schmidt's classification—where it makes up thick beds of limestone—and it is noteworthy that this horizon is practically identical with that at which *S. lithothamnioides* (Brown) occurs at Shalloch Mill.

Other specimens of *Solenopora* were collected by Prof. Nicholson in Saak, south of Reval, from the underlying Jewe beds, an horizon which corresponds very closely to that of the Craighead limestone of Girvan. Speaking of these beds, Nicholson and Etheridge remark: "At this locality *S. compacta* not only occurs as detached specimens of all sizes, but it also makes up almost entire beds of limestone; indeed, some of the bands of limestone at Saak look like amygdaloidal lavas, while others have a cellular appearance from the dissolution out of them of the little pea-like skeletons of this fossil."

In Prof. Nicholson's collection from these beds Dr. Brown afterwards distinguished two new species, namely, *S. nigra* and *S. dendriformis.* Thus in the Ordovician rocks of Esthonia, Solenopora plays quite as important a part (as a rock-forming organism) as it does in the Girvan district in Ayrshire.

In Norway again, in the Mjösen district to the north of Christiania, Solenopora occurs plentifully in Stage 5 of Kiaer's Ordovician series. Here it is very abundant and often builds entire beds, while, further east, at Furnberg, Kiaer again records the occurrence of abundant nodules of *Solenopora compacta,* var. *Peachii.*

In addition to Solenopora, however, examples of another important group of calcareous algæ, the Siphonæ, occur in great abundance in the Ordovician rocks of the Baltic region, where they play a part in the formation of calcareous rocks, scarcely less important than that played by Gyroporella and Diplopora in the rocks of the Alpine Trias.

The chief forms belong to the family of the Dasycladaceæ, represented by the recent genus Neomeris, and include the genera Palæoporella, Dasyporella, Rhabdoporella, Verimporella, Cyclocrinus, and Apidium. These algal limestones represent the beds from the Jewe to the Borckholm beds inclusive. They were originally investigated by Dr. E. Stolley, who described their occurrence in the numerous boulders which are strewn over the North German plain in Schleswig-Holstein, Pommerania, Mecklenburg, and Mark-Brandenberg. Many of these boulders can be identified by their lithological character and fossil contents as belonging to the Jewe beds of the Baltic Ordovician formations. Others have been derived from the overlying Wesenberg limestones, while yet others occur which resemble the succeeding Lyckholm beds of the Baltic succession. This assemblage proves that the boulders did not originate on the Swedish continent, but from the more easterly-lying districts, probably from a part of the Baltic between Oeland and Estland, now covered by the sea. Similar boulders are also known at Lund in Schœnen, on Bornholm, and near Wisby in the north of Gotland.

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[14] Brown, *op. cit.*, pp. 195–197.

These facts appear to show that during the deposition of the Jewe and the overlying Wesenberg and Lyckholm limestones an algal facies obtained which extended from Oeland to Estland and as far north as the Gulf of Bothnia.

But even this area does not represent the full extent of the algal limestone facies in Upper Ordovician times. In Norway, Kiaer has shown by his detailed work in the Upper Ordovician rocks, Stage 5 of the Christiania district, the important part played by the Dasycladacea in this area. Here the Gastropod limestone in places forms a "phytozoan limestone," made up of Rhabdoporella, Vermiporella, and Apidium associated with a considerable development of oolite.

Again at Kuven and Valle, in the Bergen district, Reusch and Kolderup have described knolls of crystalline limestone containing abundant remains of Rhabdoporella (formerly described as Syringophyllum) associated with a gastropod and coral fauna. This horizon they have unhesitatingly referred to zone 5*a* of Kiaer's sequence, and state that it may be found stretching from Geitero in the S.S.W. by Kuven, Valle, and Trengereid to Skarfen on Ostero, while Reusch has traced it further south to Stordo, near Dyviken and Vikenes.

We have, therefore, in Upper Ordovician times, in the north of Europe, one of the most remarkable developments of algal limestones met with throughout the geological succession. In North America also algæ are represented in Ordovician times by *Solenopora compacta*, which occurs in the Trenton and Black River limestones groups, whence it was originally obtained by Billings. It therefore occurs here at about the same horizon as in Saak and Britain.

We may also note the occurrence of Girvanella in the underlying Chazy limestone originally described by the late Prof. H. M. Seeley under the name *Strephochetus ocellatus*, but now generally admitted to be a form of Girvanella.

Other forms referred to this genus have also been reported by Schuchert from rocks of undoubted Ordovician age on the east coast of the Behring Straits.[15]

SILURIAN.

The rocks of Silurian age in Britain, in which calcareous algæ play an important part, appear to be limited to the Wenlock limestone, from which Mr. Wethered has described the constant occurrence of Girvanella tubes, especially in the beds of this age at May Hill, at Purley, near Malvern, and Ledbury.[16] Of these beds Mr. Wethered remarks: "The most interesting result of the microscopic study of these rocks was the discovery of new and interesting forms of Girvanella and the fact that this organism has taken so important a part in building up the limestone." It may here be mentioned that it was whilst studying these forms in the Wenlock limestone that Mr. Wethered first began to favour the suggestion of Rothpletz, published two years previously, in favour of Girvanella belonging to the calcareous algæ, for he remarks: "I certainly think that the forms which I have discovered in the Wenlock limestone seem more favourable to the vegetable theory of the origin of this fossil than those described in my former paper and possibly it may be allied to the calcareous algæ.'

So far as I can ascertain, this is all that has been published up to the present time with regard to the occurrence of calcareous algæ in British Silurian rocks; but I have every confidence that a more thorough microscopic examination of these rocks will reveal the presence of many other examples of this group.

Foreign Silurian.

Outside Britain at this period we find the most marked development of an algal facies, once more in the Baltic area, where, especially in the island of Gotland, algal growths contribute enormously to several of the limestones and marls. It is an interesting fact that very shortly after the disappearance of the various members of the Dasycladaceæ which were so much in evidence in Ordovician times, we have the marked development of another group of the Siphoneæ, which quickly reached a maximum, building up in their turn abundant calcareous deposits. Nodules from these limestones have long been known from Gotland under the name of "Girvanella Rock," and have been recorded by Stolley in boulders scattered over the North German plain. In 1908, however, Prof. Rothpletz showed, in his interesting work on these Gotland deposits,[17] that the forms hitherto alluded to under the term "Girvanella" were in reality referable to two different genera. One of these he showed to be a new species of Solenopora, to which he gave the name *S. gothlandica* (distinguished from *S. compacta* by the comparatively small dimension of the tubes, which are only about one quarter of the diameter of *S. compacta*, the genotype); the other he referred to his genus Spherocodium, which he had created in 1890 for certain forms from the Alpine Trias. The survival here of Solenopora into beds of undoubted Silurian age is an interesting fact and would lead us to expect that it may also some day be found in rocks of corresponding age in this country.

Of the different forms of algæ which occur in these Gotlandian deposits, perhaps the most interesting is Spherocodium. This organism occurs at several horizons in the succession. It first makes its appearance in the marl immediately overlying the Dayi flags—approximately of Lower Ludlow age—where Spherocodium occurs in considerable masses. Through the kindness of Dr. Munthe, who has made a special study of these beds in south Gotland, I have been able to examine specimens of this interesting form. In external appearance they resemble very closely nodules of Ortonella from the Lower Carboniferous of the north-west of England; some of the nodules appear to have reached a diameter of 1½ in. The bed is overlain by sandstone and oolite, which are succeeded by an argillaceous limestone rich in nodules of *Spherocodium gotlandicum* and well exposed at Grötlingbo, where it is closely associated with oolite. Among the fossils of this limestone Spherocodium itself plays a most important *rôle*.

In the overlying Iliona limestone, Spherocodium is decidedly rare, and its place is taken by nodules of Spongiostroma. It is, however, found not infrequently forming a thin crust on some of the nodules of Spongiostroma, which have also been described by Prof. Rothpletz (*op. cit.*). In appearance, Spongiostroma resembles very closely the nodules of Spherocodium, showing the same concentric arrangement round coral fragments and total absence of the radial structure which is so characteristic of Solenopora.

The actual systematic position of this organism, if organism it be, is still undecided. In his original description of this genus from the Carboniferous rocks of Belgium, Gurich refers it provisionally to the Protozoa, while Rothpletz in his description of the two species *S. balticum* and *S. Holmi* from the Gotlandian of Gotland, although admitting the difficulties of assigning it to any group of the animal kingdom, decides in favour of its hydrozoan affinities.

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[15] See Hang. 2, 1, 643.

[16] Q.J.G.S., xlix, p. 236, 1893.

[17] "Ueber Algen und Hydrozoen in Silur von Gotland und Oesel" Kungl. Sven. Vet. Handl. Band 43, No. 5, 1908.

As will be pointed out later, there appears to be no good reason why Spongiostroma may not be indirectly the result of algal growths; but whatever may be the final position assigned to it, there can be no doubt as to its importance as a rock-building form in the Iliona limestone of Gotland. The wide extent of this algæ horizon in the Upper Silurian of the Baltic area is shown by the abundance of boulders of these rocks scattered over Schleswig-Holstein, and it is probable that a careful examination will show the presence of this facies in the Silurian to the east of the Baltic provinces.

We may conclude, therefore, that the development of the Spherocodium beds of Gotland probably occupy as wide an extension in the Baltic area as that of the Rhabdoporella limestones in the Ordovician period.

With regard to other occurrences in Silurian rocks, it will be sufficient to note that of Girvanella in the Silurian limestones of Queensland, Australia, recorded by Mr. G. W. Card in 1900, and more recently by Mr. Chapman from Victoria.[18]

Quite recently Mr. R. Etheridge, jun., of Sydney,[19] has described "an organism allied to Mitcheldeania from the Upper Silurian rocks of New South Wales"; the figures given, however, and the description are not convincing that his identification can be accepted. The size of the tubes, which are from five to six times that of the largest tubes of *M. gregaria,* alone would appear to separate this organism from Mr. Wethered's genus, and almost certainly from the calcareous algæ.

DEVONIAN.

So far as I am aware, there is only one recorded occurrence of calcareous algæ in the Devonian rocks of Britain—namely, in the Hope's Nose limestone, from which Mr. Wethered has described aggregations of tubules resembling Girvanella, but in a very poor state of preservation. It is hoped that this meagre list will be increased in the near future.

Foreign Devonian.

On the Continent the records are, so far, equally poor. At the same time, the cursory examination which I was able to make of the thin sections of the Devonian limestones exhibited in the Brussels Museum leads me to expect that a careful investigation of the Belgian Devonian limestones will yield other examples besides Spongiostroma.

CARBONIFEROUS.

We now reach the period in Paleozoic times when calcareous algæ attained their maximum development in England, a development rivalling that which obtained in the Ordovician rocks of Scotland and the Gotlandian of Scandinavia. The genera here represented include Girvanella, Solenopora, and Mitcheldeania. In addition to these, there occur several lime-secreting organisms which, though still undescribed, will, I think, ultimately come to be included among the calcareous algæ. The most interesting of these organisms I have recently figured from the Lower Carboniferous rocks of Westmorland, where it forms a definite zonal horizon or "band."[20] For this form, on account of its stratigraphical importance and for facility of reference, I propose the generic name of Ortonella.[21]

Again, at the same horizon in the North-west Province I have frequently noticed concretionary deposits of limestone which occur as finely laminated masses often lying parallel to the general direction of the bedding planes, which, on microscopic examination, show no definite or regular structure, but have every appearance of being of organic origin. Many of these puzzling forms resemble very closely the somewhat obscure structures found in the Visean limestones of the Namur basin in Belgium, of which beautiful thin sections are displayed in the Natural History Museum at Brussels,[22], and which Gürich has described and figured under various names—namely, Spongiostroma, Malacostroma, &c., and included under a new family the Spongiostromidæ,[23] and a new order, the Spongiostromaceæ. He gives the following definition of the family: "Organismes marins, incrustants, coloniaux, à structure stratifiée. La structure de la colonie est indiquée, à l'état fossile, par la disposition de petits grains opaques (granulations), entre lesquels il y a des interstices, tantôt plus étroits, tantôt plus larges —canaux du tissu et canaux coloniaux—donnant naissance à un tissu spongieux. Dans plusieurs formes, on a observé des Stercomes," and suggests that they may possibly have been encrusting foraminifera.

I must confess that neither in the original sections nor in the beautiful illustrations which accompany his work can I see any grounds for referring these structures to the protozoa.

As regards the British specimens, I have long regarded them as due, directly or indirectly, to the work of calcareous algæ, on account of their intimate association with well-developed examples of these organisms, and, secondly, on account of the entire absence of foraminifera and other detrital organisms wherever this structure occurs. As, however, I have little doubt that they are closely connected in their mode of origin with the Belgian specimens, we may conveniently speak of them under the general term Spongiostroma.

Some of the best examples known to me occur associated with Ortonella in the "*Productus globosus* band" near the summit of the "*Athyris glabristria* zone" in the Shap district. They occur here in considerable masses, often many inches in thickness, and form undulating layers parallel to the bedding, and somewhat resembling huge ripple-marks. Thin sections show little definite structure, but consist of what appears to be an irregular flocculent precipitate of carbonate of lime, the interstices being filled with secondary calcite. Some of the layers resemble almost exactly, both in hand specimens and microscopic structure, the figures of *Malacostroma concentricum* given by Gürich in plates xvii. and xx. (23). Others approach closely to the same author's figures of Spongiostroma, Aphrostroma, &c. In all cases they appear to be due to the precipitation of carbonate of lime in the neighbourhood of algal growths. I have also met with similar deposits, not only at other horizons in the Lower Carboniferous of the north of England, but also in the Forest of Dean and in the rocks of the Avon Gorge; while quite recently Mr. C. H. Cunnington has sent me examples from several horizons in the Carboniferous limestones of South Wales.

Girvanella.

This organism appears to play a considerable part in the formation of calcareous deposits in the Lower Carboniferous rocks of Britain. Its presence in these rocks was first suggested by the late Prof. Nicholson,[24] in his paper where he remarks: "I have found some of the Carboniferous limestone of the north of England to contain largely an ill-preserved organism which will, I think, prove to be referable to Girvanella." This prophecy has turned out to be fully justified not only as regards the north of England, but also in the case of other Lower Carboniferous districts. In 1890 Mr. E. Wethered described[25] two new forms from the Lower Carboniferous of the Avon Gorge and Tortworth, viz., *G. incrustans,* with tubes having a diameter of 0·1 mm., and *G. Ducii* with a diameter of 0·02 mm. Mr. Wethered appears to rely chiefly on the size of the tubes for the differentiation of these species, but as this distinction was made at the time when Girvanella was still considered to belong to the Rhizopods, and as the size of the tubes frequently varies in the same specimen, it is doubtful whether these species can be maintained. Mr. Wethered's specimens were obtained from the limestone near where the Bridge Valley road joins the river bank, apparently at the base of Dr. Vaughan's Upper Dibunophyllum zone. The position of this limestone is of interest, as it appears to correspond very closely with the horizon of the Girvanella nodular bed, which forms a well-marked band at the base of the Upper Dibunophyllum zone throughout the whole of the north and north-west of England. Indeed, I have traced this band at intervals from the neighbourhood of Ford, near the Scottish border, southwards through Northumberland and the Pennine area to Penygent, and from the west coast at Humphrey Head through Arnside and Shap to the east coast, near Dunstanburgh. These organisms must, therefore, have flourished over an area of at least 3000 square miles.

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[18] Rep. Austr. Assn. Adv. Sci., 1907-8.

[19] Rec. Geol. Surv. N. S. Wales, vol. viii, pt. iv., 1909, p. 308, pl. 47.

[20] Q.J.G.S., 1912, vol. lxviii. pl. 67, fig. 2.

[21] From Orton, a village between Shap and Ravenstonedale, where this organism occurs in great abundance.

[22] One of these is also exhibited at the Jermyn Street Museum.

[23] "Mem. du Musée Roy. d'Hist. Nat. de Belgique," iii, 1906.

The Girvanella tubes found associated with these nodules usually occur in two distinct sizes having diameters of 0·03 and 0·01 mm. respectively. The two forms are closely associated, but the finer tubes occur in greater abundance, and are much more closely interlaced. They resemble Mr. Wethered's description of the two species from Gloucestershire, and the figures he gives in illustration of these might serve very well to represent our northern forms.

The best exposure showing the important development of these Girvanella nodules is to be found on the dip slopes forming the eastern shore of Humphrey Head in Morecambe Bay, where the base of the Upper Dibunophyllum zone is exposed over a considerable area.

Solenopora.

The discovery of a specimen of this genus in the Lower Carboniferous rocks of Westmorland is of considerable interest, as its occurrence here gives us some insight into the history of its wanderings between the time when we last recorded it in the Gothlandian rocks of the Baltic area, and its reappearance in the Lower Oolite of Gloucestershire. Whether it lived in the Baltic area during the Devonian and Carboniferous periods is, however, still unknown. The fact of its occurrence in the Caradoc, Carboniferous, and Jurassic rocks of the British Isles would appear to point to its existence not far off during the intervening periods, and I have hopes that before long it may be found in the Silurian, and possibly also in the Devonian rocks of this country.

In Westmorland and Lancashire Solenopora occurs in considerable abundance near the local base of the Lower Carboniferous rocks, and contributes largely to the formation of limestone deposits. It is present wherever the lowest beds of the succession are exposed, as at Shap, Ravenstonedale, and Meathop, and must formerly have flourished over a considerable area.

Though bearing a general resemblance, both in hand specimens and microscopic structure to the Ordovician and Jurassic forms, it has recently been shown by Dr. G. J. Hinde to be specifically distinct.[26] It occurs as small, spheroidal nodules up to an inch in diameter, having a markedly lobulate outline embedded in compact and usually dolomitic limestones, and it is occasionally associated with oolitic structure. When fractured, it exhibits the compact porcellanous texture and pale brownish tint characteristic of specimens of the genus found at other horizons; while weathered surfaces frequently show a concentric and occasionally a radially fibrous structure. It is noteworthy that the thallus of this organism shows no trace of dolomitisation, even when embedded in limestone containing over 30 per cent. of $MgCO_3$. The profusion of this form in Westmorland would lead one to expect its occurrence in other districts where the lowest Carboniferous zones are developed; but so far as I am aware, no such occurrence has yet been recorded. It may be of interest, therefore, to mention here that a few years ago my friend, Mr. P. de G. Benson, brought me a specimen of rock from near the base of the succession in the Avon Gorge, which on cutting I found to contain several examples of Solenopora identical with the Westmorland form. It is probable, therefore, that a careful microscopic examination of the lower horizons of the Carboniferous rocks of the south-west province will lead to the discovery of other examples of this interesting genus.

Mitcheldeania.

The specimens of *Mitcheldeania Nicholsoni* originally described by Mr. Wethered were obtained from Wadley's Quarry, near Drybrook, Mitcheldean, from the lower limestone shales at the base of the succession. Prof. Sibly, who has recently made a careful study of the Lower Carboniferous succession in the Forest of Dean,[27] has traced this algal layer over a considerable area, and considers it to represent a horizon near the top of K.I. of the Bristol sequence. He has also noted examples of Mitcheldeania at a higher level, namely, in the Whitehead limestone, an horizon corresponding probably to the base of C2. During a recent visit to the Mitcheldean district I collected specimens from both the lower shales, and also from the Whitehead limestone, and, thanks to Prof. Sibly's kind directions, I was able to see numerous sections in which he has found this algal development. There can be no doubt that Mitcheldeania is here an important rock-forming organism at least at two horizons in this district, and that it occurs over a considerable area. In the case of the upper horizon it frequently contributes largely to the rock, forming in places almost entire layers in the Whitehead limestone. As regards the forms met with at these two horizons, the upper form found in the Whitehead limestone agrees exactly in general characters and mode of occurrence, and also in detailed microscopic structure, with Nicholson's species, *M. gregaria,* from Kershope Foot. The character of the two sets of tubes, their size and mode of arrangement is identical, and it is impossible to distinguish between sections of well-preserved specimens from the two localities. Unfortunately, the specimens from the lower shales at Mitcheldean are very badly preserved, but if Nicholson's distinction between the two species holds, we shall have to speak of the form from the lower horizon at Mitcheldean as *M. Nicholsoni,* and that from the Whitehead limestones as *M. gregaria.* Frequently associated with the latter is a curious *festoon-like* growth, while a Spongiostroma-like structure is often found in the matrix of the rock between the larger tubes of *M. Nicholsoni.* Some years ago Mr. Wethered also recorded a similar form of Mitcheldeania from the base of the middle limestones of the Avon Gorge, while I have myself collected nodules containing specimens apparently referable to *M. Nicholsoni* from the Modiola Shales near the base of the succession. Interesting as the development of Mitcheldeania in the Forest of Dean undoubtedly is, its real home in Britain is in north Cumberland and the Scottish border, where it flourished to a remarkable extent in the shallow water lagoons which spread over so large an area in the north of England during early Carboniferous times. Over the greater part of north Cumberland and the east of Roxburgh we find a remarkable development of algal limestones in the formation of which Mitcheldeania plays a very important part. They are met with especially at two horizons, an upper one, lying immediately below the Fell Sandstone, and a lower one in the middle of the underlying series of limestone and shales. The lower horizon is especially interesting on account of the thick masses of limestone composed almost entirely of algal remains. Though Mitcheldeania forms the basis of this reef-like development, it is accompanied by other algal forms, especially bundes of minute tubules of Girvanella and coarser tubes reminding one of the Spherocodium of Gotland. In places again the marked concentric coatings resemble certain forms of Spongiostroma. The substance of the reef has frequently formed round the remains of Orthoceratites; indeed, the chief layer is usually associated with remains of these Cephalopoda. With other layers occur tubes of Serpulæ, and others again with ostracod remains. In addition to the limestone of this massive reef, abundant nodules lie scattered through the calcareous shales above and below.

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[24] *Op. cit.* p. 24.

[25] *Q. J. G. S.*, vol. 47, p. 280, pl. 11, figs. 1 and 2. 1890.

[26] *Geol. Mag.*, Dec. 5, x, 289. 1913.

[27] *Geol. Mag.*, Dec. 5, 417.

The upper layer, which includes examples from Nicholson's type locality, forms a compact limestone several inches thick. It is made up of small spheroidal nodules about half an inch in diameter, and occurs a short distance below the Fell Sandstone. It can be traced over the whole of north Cumberland and north-west Northumberland from near Rothbury on the east to the Scottish border at Kershope Foot, and from the head waters of the Rede in the north, to the Shopford district in the south. This layer must therefore have been originally deposited over an area of at least 1000 square miles. The horizon of the upper band is almost certainly that of the C. zone of the Bristol sequence.[28] It is quite possible, therefore, that it is contemporaneous with the Whitehead limestone of Mitcheldean. This supposition receives support from two other pieces of evidence. In the beds underlying the *Mitcheldeania gregaria* band in north Cumberland occur calcareous nodules largely made up of tubes of Serpulæ—an organism which is completely absent from the Westmorland succession, but which is reported by Prof. Sibly from the lower limestone shales containing Mitcheldeania in the Forest of Dean district. Again, this upper algal layer in Northumberland and Cumberland is almost immediately overlain by the Fell Sandstone series, while the Whitehead limestone at Mitcheldean passes immediately upwards into a sandstone, the Drybrook Sandstone of Prof. Sibly, which was originally correlated with the Millstone Grit, but was shown by Dr. Vaughan in 1905 to belong to the Lower Carboniferous series. It would be interesting if further researches should prove the existence of a former gulf at the end of Tournaisian times, running to the east of the North Wales Island, from the Forest of Dean through north Cumberland to the southern slopes of the Cheviot Isle, with a branch given off towards eastward into Westmorland.

In any case, it is a remarkable fact that we have a great development of algal deposits at this period in Gloucestershire, Westmorland, Lancashire north Cumberland, and Northumberland.

Ortonella

This form, as already mentioned, occurs in great abundance in the algal band in the "*Athyris glabristria* zone" of the north-west province It is found in spherical nodules up to the size of a small orange. In microscopic sections it resembles Mitcheldeania in so far as it consists of a series of tubes growing out radially from a centre. It differs, however, from this genus in many important respects. All the tubes are approximately of the same size, and there is no evidence of alternating coarse and fine turfs arranged concentrically, as in the case of Mitcheldeania. Further, the tubes are not undulating as in that genus, and therefore in thin slices lie for a long distance in the plane of the section. They are much more widely spaced and show marked dichotomous branching, bifurcation making a nearly constant angle of about 40°, and there is a strong tendency for the branching to take place in several tubes at about the same distance from the centre of growth, producing a general concentric effect in the nodule.

The diameter of the tubes is decidedly less than those in Mitcheldeania, being usually little more than half the size of the tubes of *M. gregaria* The nodules of this genus occur in great profusion, contributing largely to the formation of the shaley dolomite at the base of the "*P. globosus* band" throughout the Shap, Ravenstondale, and Arnside districts and Westmorland and Lancashire.

In addition to these genera there occur also two other encrusting calcareous growths which require mention. The first of these appears in thin sections in the form of a *festoon-like growth,* surrounding fragments of calcareous algæ, especially Mitcheldeania and Ortonella. I have met with it abundantly in the "Algal band" in the north-west of England, but it also occurs not infrequently associated with Mitcheldeania in the Whitehead limestone in the Forest of Dean, while a similar structure occurs associated with *Mitcheldeania gregaria* in north Cumberland.

Although the exact nature of this growth is still undecided, I mention it here on account of its invariable association with undoubted calcareous algæ.

The other deposit is the form already alluded to under the term Spherocodium, which I have found forming considerable masses of rock in many districts where the Lower Carboniferous beds are exposed; not only in Westmorland and north Cumberland, but also in the Bristol district, the Forest of Dean, and South Wales.

Foreign Carboniferous.

From its general similarity to the British deposits we might expect to find examples of an algal development in some portion of the Belgian Lower Carboniferous succession. As already mentioned, large masses of encrusting calcareous deposits have been described by Gürich[29] from the Visean limestones of the Namur basin as Spongiostroma, &c., which, though referred by him to the Rhizopoda, may very well be calcareous precipitates deposited by algal influence. Many of these deposits are similar to those mentioned above from British rocks.

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[28] "Geology in the Field," pt. 4, p. 683, and *Q. G. S.*, vol. 73, 1912, p 547.

[29] "Les Spongiostromides du Viséen de la Province de Namur. Mem. du Musée Roy. d'Hist. Nat. de Belgique," t. iii 1906.

No undoubted remains of calcareous algæ have, however, yet been recorded from these Belgian rocks. It may be of interest, therefore, to mention the recent discovery by Prof. Kaisin, of Louvain, of undoubted algal remains in the beds overlying the Psammites-de-Condroz at Feluy, on the Samme. The form found here resembles Ortonella of the Westmorland rocks, but the tubes are much finer, and it may turn out to represent a species of Micheldeania. During a recent visit to Belgium I had the pleasure of visiting the Comblain au Pont beds, in the Feluy section, with Prof. Kaisin, and, although these beds have been previously classed as Devonian, I agree with him that they probably belong to the base of the Carboniferous, and correspond approximately to K of the Bristol sequence. In the company of Prof. Dorlodot and Dr. Salée, I also visited the chief sections of the Visean, and we succeeded in discovering at least three horizons at which nodular concretionary structures, probably referable to algal growths, occurred. It is pretty certain, therefore, that careful microscopic investigation of the Belgian rocks will show the presence of calcareous algæ at more than one horizon.

One other occurrence of Girvanella may be mentioned from foreign Carboniferous rocks: that is a form described by Mr. H. Yabe from the (?) Carboniferous rocks of San-yu-tung and other localities in China under the name of *G. sinensis*.[30]

PERMIAN AND TRIAS.

In Britain I have met with no reference to the occurrence of calcareous algæ in rocks of this period, but quite recently Mr. Cunnington, of H.M. Geological Survey, sent me a few nodules from the base of the Permian which resemble very closely fragments of Spongiostroma from the Carboniferous limestone, and may be derived from that formation.

Abroad, masses of limestone, composed almost entirely of remains of Diplopora and Gyroporella, have long been known from the Muschelkalk and lower Keuper beds of the eastern Alps, notably the Mendola Dolomite, the Wetten limestone of Bavaria, and the Tyrolian Alps—from the Zugspitz to Berchtesgaden. In the Hauptdolomit and from the Fassa Dolomite of the north limestone Alps and the stratified Schlern dolomite of the southern Tyrol. In the Lombard Alps the same facies reappears, and *Diplopora annulata* occurs abundantly in the well-known Esino limestone above Varenna.

In 1891 Rothpletz[31] showed that certain spherical bodies in the Triassic beds of St. Cassian, formerly regarded as oolitic structures, were in reality algal growths, and referred them to a new genus, Sphœrocodium, on account of their apparent resemblance to the living form Codium. He describes them as encrusting organisms forming nodules up to several centimetres in diameter. They contribute substantially to the rocks in which they occur, and are found especially in the Raiblkalk, the Kossenerkalk, and the Plattenkalk.

JURASSIC.

The Mesozoic rocks of Britain contain but few examples of marine algal limestones, and important occurrence are confined to the Jurassic Rocks. The forms met with are limited to two genera, Girvanella and Solenopora.

Tubes of Girvanella occur fairly abundantly in the British Oolites, especially in the well-known Leckhampton Pisolites, and Mr. Wethered, who has made a special study of oolitic structures, appears inclined to refer all oolitic structures to organic agency of this nature.

The examples of Solenopora met with in the Great Oolite and Coral Rag are of special interest. In both cases they attain very much larger dimensions than any species yet discovered in the Palæozoic rocks.

At Chedworth, near Cirencester, I have collected masses of *Solenopora jurassica,* measuring up to a foot across, in which the original pink tint is still so conspicuous on freshly fractured surfaces as to give rise to the local appellation of "Beetroot Stone," and the colour also reminds one of the red algæ growing in great profusion at the present day in the Gulf of Naples.

It is also recorded from the same horizon by Dr. Brown from Malton in Yorkshire, and also, on the authority of the late Mr. Fox Strangways, by Prof. Rothpletz. (*Op. cit.*)

In Yorkshire, however, a form undoubtedly occurs at a higher horizon, namely, in the Coral Rag of the Scarborough district, where it is well known to local collectors. Specimens which I have collected from this horizon at Yedmandale and Seamer also attain a considerable size—up to six inches in their longest dimension.

The name *S. jurassica* was given by Prof. Nicholson in manuscript to the specimens from Chedworth, and was adopted by Dr. Brown in his description of specimens from both Chedworth and Malton.

Prof. Rothpletz points out that specimens examined by him from Yorkshire differ from the genotype in the fact that the cells are typically rounded in cross section and by the absence of perforations in the cell-walls, and he therefore proposes to separate it as a new genus Solenoporella. It seems probable that some confusion has arisen between the specimens to which Nicholson originally gave the name of *S. jurassica* from the Great Oolite of Chedworth and other specimens from a higher horizon—the Coral Rag—examined by Dr. Brown and Prof. Rothpletz.

The former indeed figures a longitudinal section from Chedworth (Glos.) and a tangential section from Malton (Yorkshire).

I have collected specimens from both horizons and consider that whilst the Chedworth specimen, to which the name *Solenopora jurassica* was originally given, represents a species of true Solenopora, showing closely packed cells with polygonal outline in tangential section, the form from the Coral Rag of Yorkshire, with distinct circular outline to the tubes in tangential section is specifically, if not generically, distinct, and is that described by Rothpletz as Solenoporella.

If this view be correct we should continue to speak of the specimens from the Great Oolite at Chedworth as *Solenopora jurassica,* while those from the Coral Rag of Yorkshire must be known as Solenoporella *sp.* Rothpletz.

Foreign Jurassic.

It is surprising that records of the occurrence of calcareous algæ in foreign Jurassic rocks are at present very scarce.

Quite recently, however, Mr. H. Yabe[32] has described a new species of Solenopora, under the title *Metasolenopora Rothpletzi,* from the Torinosu limestone Japan. This discovery is of interest, as it carries the known occurrence of Solenopora up to the base of the Cretaceous, in which formation Lithothamnion appears and thenceforward becomes the chief representative of the rock-building coralline algæ.

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[30] H. Yabe, "Science Reports of the Tâhoku Imp. Univ.," Japan, 1912.

[31] "Zeitsch. d. deut. Geol. Ges.," 1891.

[32] *Op. cit.*, p. 2

CRETACEOUS.

We here reach the period when Lithothamnion and its allies begin to make their appearance. They have not yet been recognised in British rocks, but are widely distributed in Continental deposits. They occur in the Cenomanian of France, in the Sarthe and the Var, but especially in the Danian of Petersburg, near Maestricht.

Other forms which may be mentioned are Diplopora and Triploporella. The former is met with abundantly in the lower Schrattenkalk in certain districts, especially Wildkirchli, where it plays a considerable part in the formation of the deposit.[33]

TERTIARY.

In Britain no important deposits of marine calcareous algæ have yet been reported, but considerable deposits of limestone, rich in remains of Chara, have for long been known from the Oligocene of the Isle of Wight.

Foreign Tertiary.

On the Continent, however, large deposits rich in Lithothamnion and Lithophyllum have been known for many years, among which I may mention the well-known Leithakalk of the Vienna Basin and Moravia. It will be remembered that it was these deposits which formed the subject of Unger's important monograph in 1858.

CONCLUSIONS.

The facts given above regarding the geological distribution and mode of occurrence of these organisms lead us to several interesting conclusions. In addition to the evidence of the important part they play as rock-builders, it is evident that certain forms flourished over wide areas at the same geological periods, and might well be made use of in many cases with considerable reliability as proofs of the general contemporaneity of two deposits. Thus, as general examples, we may cite the wide distribution of *Solenopora compacta* in the Baltic provinces, Scotland, England, Wales, and Canada during Llandilo-Caradoc times.

The wonderfully persistent development of the *Rhabdoporella* facies over the whole of the Baltic area at the close of Ordovician times was of so marked a character that by means of boulders scattered over the north German plain it can even be made use of for tracing the direction of flow of the ice-sheet during glacial times.

Again, to take examples nearer home. The Ortonella band found throughout Westmorland and north Lancashire near the summit of the Tournaisian occurs so constantly at the same horizon as to constitute one of the most valuable zonal indices in the succession of the north-west province, and can be used with the greatest confidence not only for correlating widely separated exposures, but also affords valuable evidence in the case of tectonic movements. Other examples are supplied by the "Girvanella nodular band" at the base of the Upper Dibunophyllum zone, and the *Mitcheldeania gregaria* beds in the north of England and the Forest of Dean.

Again, the presence of these organisms at a particular horizon furnish us with interesting evidence as to the conditions which obtained during the accumulation of these deposits.

At the present day calcareous algæ flourish best in clear but shallow water in bays and sheltered lagoons. As a good example we may take the algal banks in the Bay of Naples, described by Prof. Walther,[34] where Lithothamnion and Lithophyllum flourish to a depth of from 50–70 metres. There is seldom any muddy sediment on these banks, though detrital limestone fragments are widely distributed. Another interesting point is the constant association of fossil calcareous algæ with oolitic structure and also with dolomite.

Thus oolites occur in connection with Solenopora in the lower Cambrian of the Antarctic, in the Craighead limestone at Tramitchell in the Ordovician rocks of Christiania and the Silurian of Gotland and in the Lower Carboniferous limestone of Shap; while in the Jurassic rocks of Gloucestershire and Yorkshire it occurs in the heart of the most typical oolitic development to be met with in the whole geological succession. Though Mr. Wethered has made out a good case for the constant association of Girvanella tubes with oolitic grains, there are many cases in which their association cannot be traced. M. Cayeux,[35] in writing of a mass of Girvanella from the ferruginous oolites of the Silurian rocks of La Ferrière-aux-Etangs, expresses his opinion that Girvanella encrusts the oolite grains but does not form them, and that it is really a perforating alga of a parasitic nature.

The presence of dolomites in connection with algal deposits at different geological horizons appears to have taken place under definite physiographical conditions similar to those which obtain to-day in the neighbourhood of coral reef. Such lagoon conditions would come into existence *either* during a period of subsidence *or* elevation, and this is just what we find when we examine the periods at which these reefs are most persistent.

Thus the Girvan Ordovician reef occurred during an elevation which culminated with the deposition of the Benan Conglomerate; the Lower Carboniferous Algal band in Westmorland was laid down during the subsidence which followed the Old Red Sandstone Continental period of the Upper Girvanella; modular band occurred when the Marine period of the Lower Carboniferous was drawing to a close and a general elevation was taking place. Similar conclusions could be drawn from other periods recorded above did time permit.

In concluding this address, I wish to express the hope that however imperfect the account I have given of the succession of forms may be, that it will help to stimulate an interest in these rock-building algæ and encourage geological workers in this country to turn their attention to a hitherto neglected group of forms of great stratigraphical importance.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

LEEDS.—Dr. Charles Crowther, formerly lecturer in agricultural chemistry, has been appointed professor in that subject, and will have charge of the experiments in animal nutrition, which are being supported by a grant from the Development Commissioners.

The Council of the University has granted six months' leave of absence to Prof. Smithells, who is leaving England on September 26 to proceed to Lahore, where he is to give a course of lectures and to assist the Punjab University in other ways in the promotion of scientific education and research.

The position of research chemist to the Joint Committee on Ventilation Research of the Institution of Gas Engineers and of the University of Leeds has

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[33] Lorenz, 1908.

[34] "Zeitsch. d. deut. Geol. Ges." 1885, p. 230, and "Abh. d. Königl. Preuss. Akad. der Wiss," 1910.

[35] *Comptes Rendus Acad. de Sci.*, 1910, p. 359.